APPENDIX A

CONTROL CHART VARIABLES DATA (X-BAR & R)

DATA PASSED NORMALITY TEST YES NO

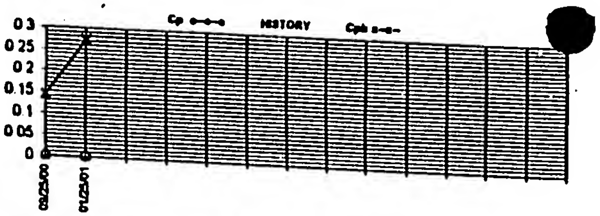
MEASUREMENT GAGE TO USE: PELT GAGE
BACKUP MEASUREMENT GAGE: ELCOMETER
SC#: 0
PLANT: DEMO
DEPARTMENT: PAINT
DATA CONTROL LIMITS CALCULATED FROM: 9/25/00
ENGINEERING SPECIFICATION: 0.90 Minimum Unilateral
DATE OF MEASUREMENT STUDY / P VALUE (%):
BADGE NO: PRIME BOOTH
PANEL: Left
CHARACTERISTIC: Taupe Prime
SAMPLE SIZE: 1 UNIT
SAMPLE FREQUENCY: 2/SHIFT
CONTROL ITEM: YES ☐ NO ☐
LOCATION DATA COLLECTED: PELT BOOTH
CHART CHAMPION: FILM ANALYST
CHART BUDDY: PROCESS ENGINEER
LINE X LIMITS: CALCULATED
BAR A - INITIAL LIMITS: HISTORICAL
BAR B - PREVIOUS LIMITS: HISTORICAL
LAST CALCULATED LINE X LIMITS: 10/10/00 to 03/21/01
HISTORICAL LINE X LIMITS: na to na

UCLX 1.20	CLX 1.07	LCLX 0.94	UCLR 1.29	CLR 0.83	LCLR 0.38	LINE X-BAR na	LINE R-BAR na	
UCLX 0.00	CLX 0.00	LCLX 0.00	UCLR 0.00	CLR 0.00	LCLR 0.00	CP 0.000	CPK 0.272	
						CP 0.000	CPK 0.000	

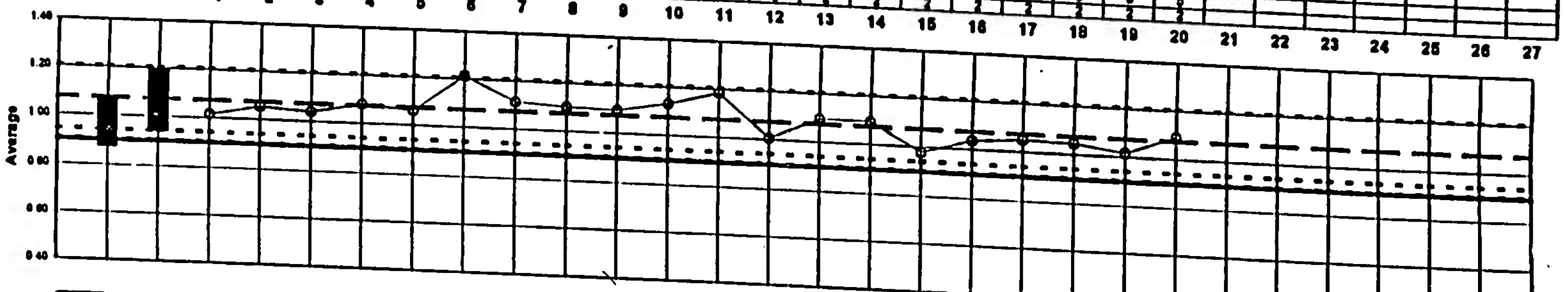
Unit of Measure MIL

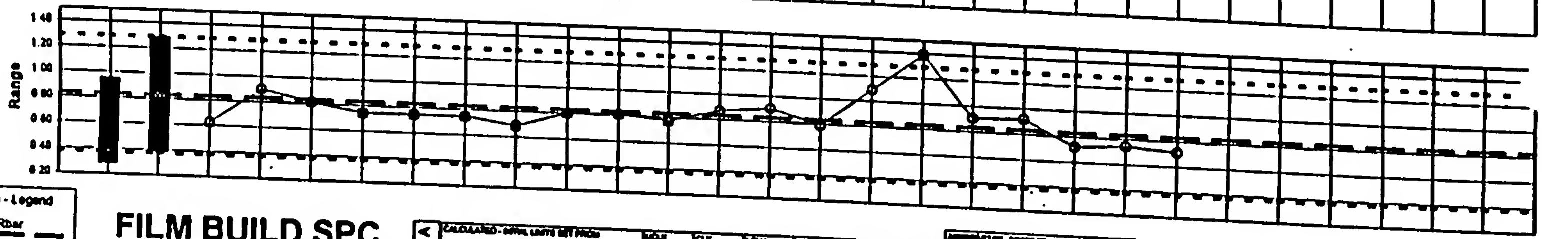
Date	10/10	10/12	10/18	10/23	10/23	10/27	10/31	10/31	11/7	11/10	11/13	11/20	11/23	11/27	11/28	11/29	12/4	12/8	12/8	3/21							
Average	1.02	1.05	1.04	1.08	1.06	1.21	1.11	1.10	1.09	1.13	1.18	1.01	1.09	1.09	0.98	1.03	1.05	1.05	1.02	1.09							
Range	0.62	0.90	0.81	0.74	0.74	0.74	0.68	0.80	0.81	0.77	0.87	0.90	0.79	1.09	1.39	0.90	0.92	0.72	0.74	0.71							
Minimum	0.708	0.605	0.587	0.701	0.622	0.812	0.737	0.69	0.648	0.737	0.744	0.587	0.648	0.581	0.45	0.594	0.587	0.666	0.639	0.711							
Maximum	1.33	1.503	1.4	1.439	1.365	1.555	1.421	1.488	1.457	1.511	1.615	1.486	1.439	1.67	1.835	1.493	1.503	1.385	1.382	1.423							
Style	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	5							
Shift	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2							
A B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

REACTION PLAN #



Average - Legend
CLXbar
UCLXbar/LCLXbar
LSL





Range - Legend
Rbar
UCLRbar/LCLRbar

FILM BUILD SPC

PAINT APPLICATIONS TEAM

BAR A	CALCULATED - INITIAL LIMITS SET FROM na to na	UCLX na	CLX na	LCLX na	UCLR na	CLR na	LCLR na
	HISTORICAL - INITIAL LIMITS SET FROM [illegible] to [illegible]	UCLX 1.07	CLX 0.97	LCLX 0.87	UCLR 0.96	CLR 0.62	LCLR 0.28
BAR B	CALCULATED - PREVIOUS LIMITS SET FROM na to na	UCLX na	CLX na	LCLX na	UCLR na	CLR na	LCLR na
	HISTORICAL - PREVIOUS LIMITS SET FROM 10/10/00 to 3/12/01	UCLX 1.20	CLX 1.07	LCLX 0.94	UCLR 1.29	CLR 0.83	LCLR 0.38

[illegible] SECTION
NOTE: USER MAKES DECISION CONCERNING NORMALITY
LINE X BAR AND [illegible] TO SHIFT WITH CONTROL LIMITS
SPECIFICATION LIMIT FILTER OPTION IS DISPLAYED

APPENDIX B

INDIVIDUAL MOVING RANGE CONTROL CHART

DATA PASSED NORMALITY TEST YES NO

PELT GAGE
0
MACH NO
PRIME BOOTH
SAMPLE SIZE
LOCATIONS DATA COLLECTED
PELT BOOTH
LINE LIMITS
CALCULATED

BAR A - INITIAL LIMITS
DISABLED

Unit of Measure MIL

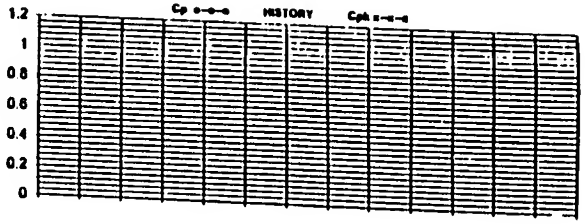
PLANT
DEMO
ENGINEERING SPECIFICATION
0.00 Minimum Unilateral
PART
Specific Point
POINT
22
SAMPLE FREQUENCY
2/SHIFT
CHART CHAMPION
FILM BUILD ANALYST
BAR B - PREVIOUS LIMITS
DISABLED

MEASUREMENT GAUGE
ELCOMETER

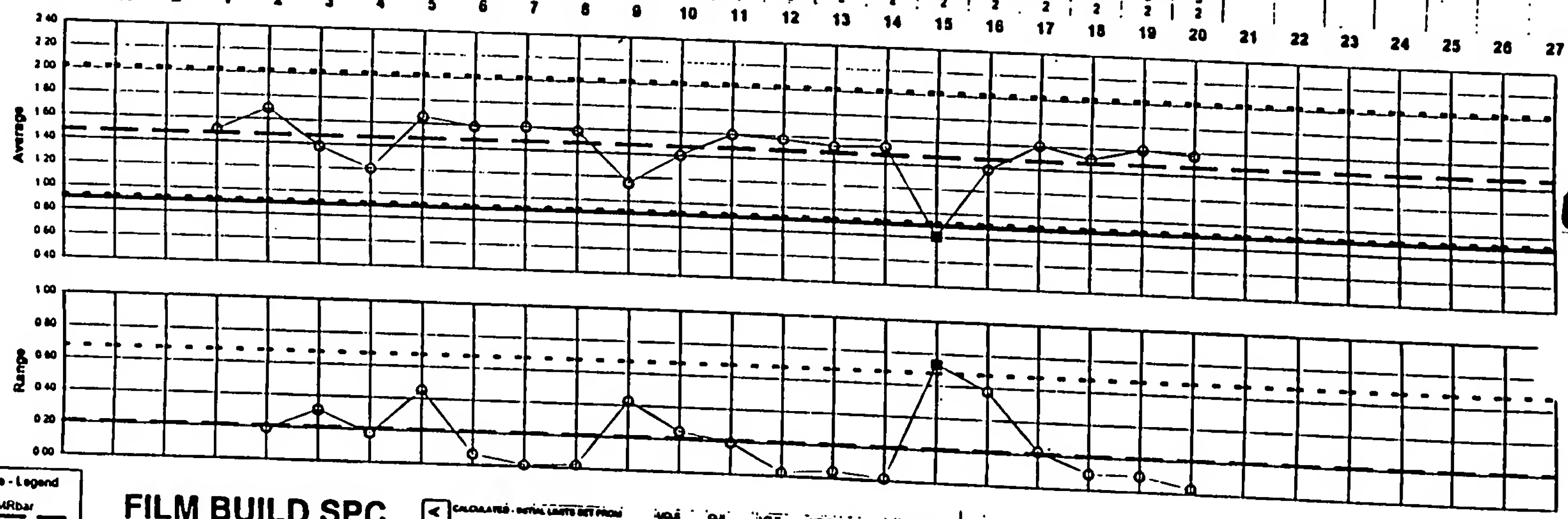
DEPARTMENT
PAINT
DATE OF MEASUREMENT STUDY / P VALUE
CHARACTERISTIC
Taupe Prime
CONTROL ITEM
YES ☐ NO ☐
CHART BUDDY
PROCESS ENGINEER

				UCLX	CLX	LCLX	UCLR	CLR	LCLR	CP	CPK
LAST CALCULATED LINE LIMITS	10/10/00	to	12/21/01	2.03	1.47	0.92	0.68	0.21	na	0.000	1.040
HISTORICAL LINE LIMITS	na	to	na	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000

REACTION PLAN #



	A	B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Date			10/10	10/12	10/18	10/23	10/23	10/27	10/31	10/31	11/7	11/10	11/13	11/20	11/23	11/27	11/28	11/29	12/4	12/8	12/8	12/21							
Value			1.50	1.69	1.38	1.21	1.68	1.59	1.60	1.58	1.15	1.40	1.60	1.57	1.53	1.54	0.81	1.39	1.61	1.51	1.61	1.57							
Range				0.19	0.31	0.18	0.45	0.07	0.01	0.02	0.43	0.25	0.19	0.03	0.04	0.01	0.73	0.58	0.22	0.10	0.10	0.03							
Style			5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	5	6	6	5							
Shift			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2							



Average - Legend
CLXbar
UCLXbar/LCLXbar
USL/LSL

Range - Legend
MRbar
UCLMRbar/
LCLMRbar

FILM BUILD SPC

PAINT APPLICATIONS TEAM

BAR A	CALCULATED - INITIAL LIMITS SET FROM	na to na	UCLX na	CLX na	LCLX na	UCLR na	CLR na	LCLR na
	HISTORICAL - INITIAL LIMITS SET FROM	na to na	UCLX 0.00	CLX 0.00	LCLX 0.00	UCLR 0.00	CLR 0.00	LCLR 0.00
BAR B	CALCULATED - PREVIOUS LIMITS SET FROM	na to na	UCLX na	CLX na	LCLX na	UCLR na	CLR na	LCLR na
	HISTORICAL - PREVIOUS LIMITS SET FROM	na to na	UCLX 0.00	CLX 0.00	LCLX 0.00	UCLR 0.00	CLR 0.00	LCLR 0.00

APPENDIX C

FILM BUILD EXECUTIVE SCHEMATIC (RIGHT AND LEFT SIDES)

MEASUREMENT GAUGE TO USE
PELT GAGE
UNIT OF MEASURE
MIL
MACH. NO.
PRIME BOOTH
SAMPLE SIZE

CHART CHAMPION
FILM ANALYST

PLANT
DEMO
PANEL
<Exec. Schematic>
SAMPLE FREQUENCY
2/SHIFT
CHART BUDDY
PROCESS ENGINEER

BACKUP MEASUREMENT GAUGE
ELCOMETER

DEPARTMENT
PAINT
CHARACTERISTIC
Taupe Prime
LOCATIONS DATA COLLECTED
PELT BOOTH
EXECUTIVE SCHEMATIC SUBGROUP
10/10/00 to 03/21/01

MIN - AVG - MAX		MIN - 6SIGMA - MAX	
0.80	1.10	0.00	1.00

BOOTH
na

LEGEND

Average (X)	6 Sigma (s*6)

Data out of spec is underlined and shaded

DATA RECORD COUNT
20

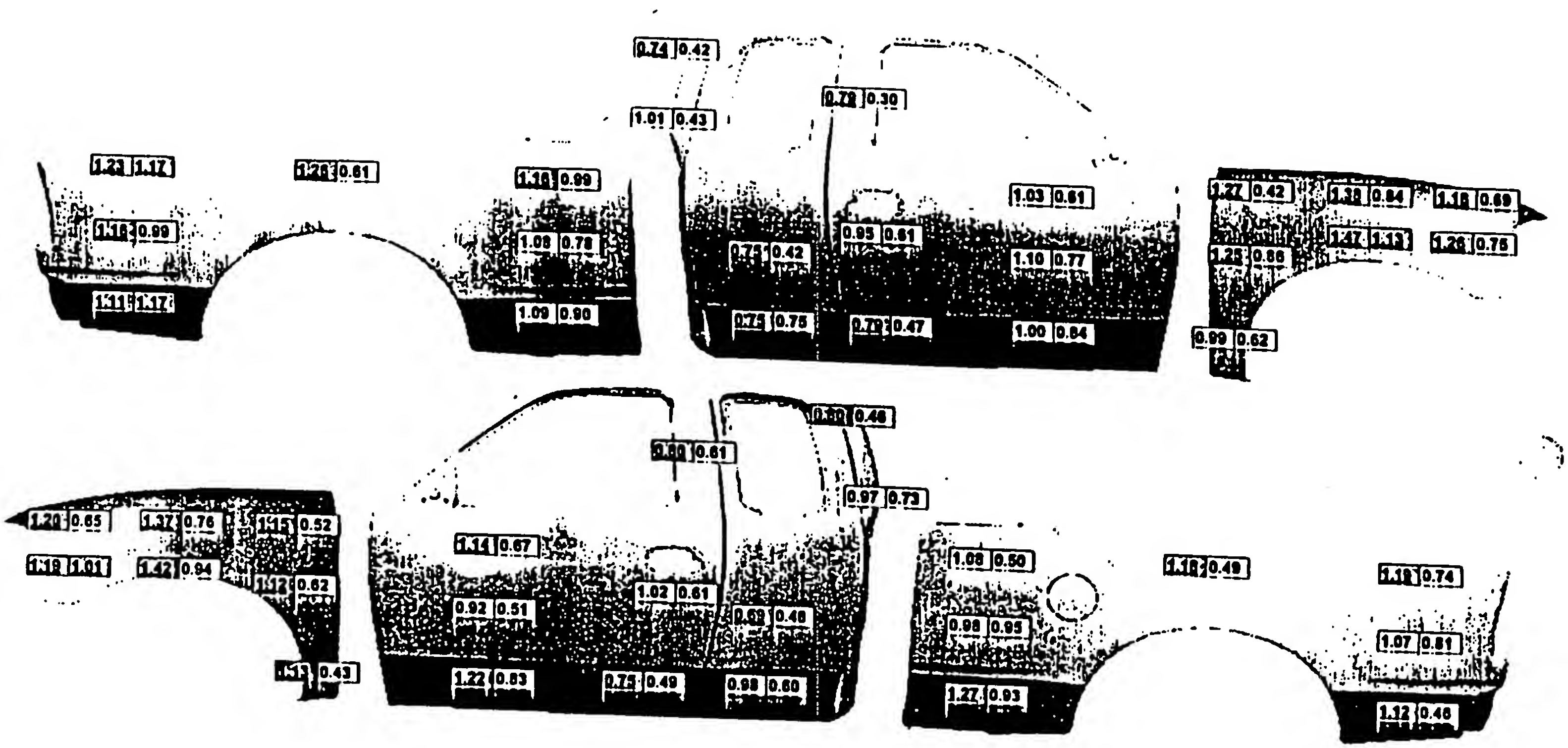
FILM BUILD SPC

PAINT APPLICATIONS TEAM

ANNOTATION SECTION

Retrieval System allows storage of Schematic for electronic distribution and review.

Profile includes coatings' averages, process performance and the number of units measured.



APPENDIX D

Film Build Cpk's Cost Impact Analysis

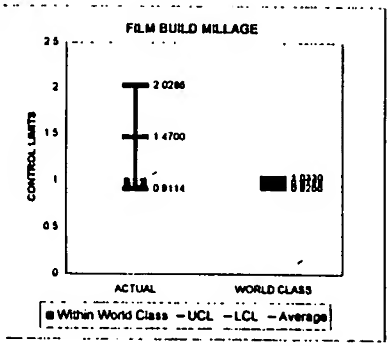
1ST PREMISE

VARIATION SELECTION
1) Choose Variability
2) Select First Target Range
3) Average Adjusted to World Class Standard

Coating. Taupe Prime
Point 22
Booth na

Coating Min Spec.:	0.9
Actual Average.	1 47
Actual Range	0 21
Actual Cpk.	1 04
Target Range:	0.02
World Class Cpk:	1 5
Effect on Coating Usage	-33.35%

Approximate Annualized Cost Impact
$ (1,418.12)



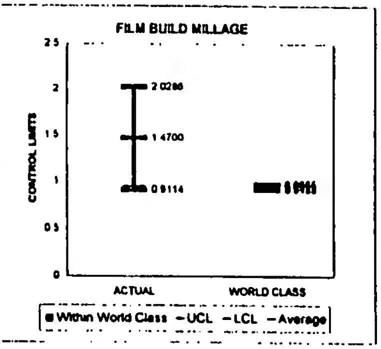
2ND PREMISE

VARIATION SELECTION
1) Choose Variability
2) Select Second Target Range
3) Average Adjusted to World Class Standard

Coating. Taupe Prime
Point: 22
Booth: na

Coating Min. Spec.:	0 9
Actual Average:	1 47
Actual Range:	0 21
Actual Cpk:	1 04
Target Range:	0.01
World Class Cpk:	1 5
Effect on Coating Usage	-36.06%

Approximate Annualized Cost Impact
$ (1,533.52)



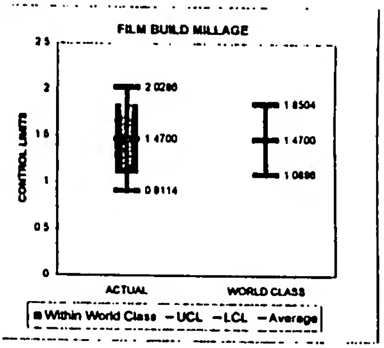
3RD PREMISE

VARIATION REDUCTION
1) Variability Adjusted to World Class Standard
2) Coating Usage Remains Consistent
3) Average Remains Constant

Coating: Taupe Prime
Point: 22
Booth. na

Coating Min Spec.:	0.9
Actual Average:	1 47
Actual Range:	0 21
Actual Cpk:	1 04
New Range:	0.14
World Class Cpk:	1.5
Effect on Coating Usage	0.00%

Approximate Annualized Cost Impact
$ nil



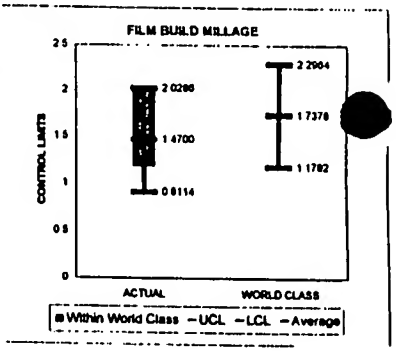
4TH PREMISE

INCREASED MILLAGE
1) Coating Usage Increases
2) Variability Remains Constant
3) Average Adjusted to World Class Standard

Coating: Taupe Prime
Point. 22
Booth: na

Coating Min. Spec.:	0 9
Actual Average:	1.47
Actual Range:	0.21
Actual Cpk:	1 04
New Average:	1.74
World Class Cpk:	1.5
Effect on Coating Usage	18.22%

Approximate Annualized Cost Impact
$ 774.61



Cost per Unit Factors:							
Coating. Taupe Prime	Point: 22	Usage per Unit (gal.). 0 27	Cost per Gallon ($) 30 00	Coating Popularity %: 25	Point % 1 05	Booth % Flow: 100	Annualized Production (units): 200,000

APPENDIX E

CONSTANTS AND FORMULAS

FORMULA FOR $\bar{X}$ AND R CHARTS

$\bar{X}$ - Chart

$$\bar{X} = \frac{\Sigma X}{n}$$

$$CL\bar{X} = \bar{\bar{X}} = \frac{\Sigma \bar{X}}{k}$$

$$UCL\bar{X} = \bar{\bar{X}} + (A_2 \times \bar{R})$$

$$LCL\bar{X} = \bar{\bar{X}} - (A_2 \times \bar{R})$$

R - Chart

$$CLR = \bar{R} = \frac{\Sigma R}{k}$$

$$UCLR = D_4 \times \bar{R}$$

$$LCLR = D_3 \times \bar{R}$$

$$\hat{\sigma} = \frac{\bar{R}}{d_2}$$

$$Cp = \frac{USL-LSL}{6\hat{\sigma}}$$

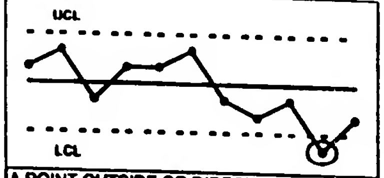
$$Cpk = \text{minimum of } \frac{USL-\bar{\bar{X}}}{3\hat{\sigma}} \text{ or } \frac{\bar{\bar{X}}-LSL}{3\hat{\sigma}}$$

CONTROL CHARTS FOR VARIABLE DATA

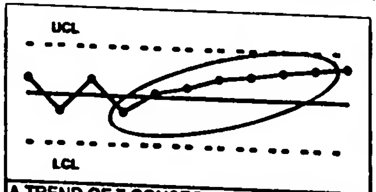
x	Individual Measurement
$\bar{X}$	Subgroup Average
$\bar{\bar{X}}$	Grand Average
Σ	Sum of
R	Range = Highest Value - Lowest Value
CL	Center Line
UCL	Upper Control Limit
LCL	Lower Control Limit
k	Number of Subgroups
n	Subgroup Size
$\hat{\sigma}$	Process Standard Deviation
A_2	Factor for $\bar{X}$ Chart Limits
D_4	Factor for UCL on R Chart
D_3	Factor for LCL on R Chart
USL	Upper Specification Limit
LSL	Lower Specification Limit
d_2	Factor for estimating Process Standard Deviation

Chart X	
n	A2
Subgroup Size	Upper and Lower Control Limit Factor
2	1.880
3	1.023
4	0.729
5	0.577
6	0.483
7	0.419
8	0.373
9	0.337
10	0.308
11	0.285
12	0.266
13	0.249
14	0.235
15	0.223
16	0.212
17	0.203
18	0.194
19	0.187
20	0.180
21	0.173
22	0.167
23	0.162
24	0.157
25	0.153

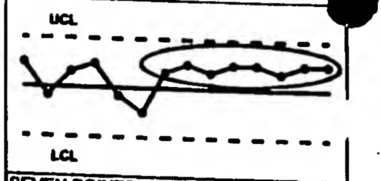
Range Chart R			
n	d2	D3	D4
Subgroup Size	Estimate of Standard Deviation Divisor	Lower Control Limit Factor	Upper Control Limit Factor
2	1.128	na	3.270
3	1.693	na	2.574
4	2.059	na	2.282
5	2.326	na	2.114
6	2.534	na	2.004
7	2.704	0.076	1.924
8	2.847	0.136	1.864
9	2.970	0.184	1.816
10	3.078	0.223	1.777
11	3.173	0.256	1.744
12	3.258	0.283	1.717
13	3.336	0.307	1.693
14	3.407	0.328	1.672
15	3.472	0.347	1.653
16	3.532	0.363	1.637
17	3.588	0.378	1.622
18	3.640	0.391	1.608
19	3.689	0.403	1.597
20	3.735	0.415	1.585
21	3.778	0.425	1.575
22	3.819	0.434	1.566
23	3.858	0.443	1.557
24	3.895	0.451	1.548
25	3.931	0.459	1.541



A POINT OUTSIDE OR DIRECTLY ON THE CONTROL LINE



A TREND OF 7 CONSECUTIVE POINTS MOVING IN THE SAME DIRECTION, EITHER UPWARD OR DOWNWARD INDICATES A GRADUAL CHANGE IN THE PROCESS



SEVEN POINTS ABOVE THE CENTRAL LINE INDICATE THAT THE CENTER OF THE NORMAL DISTRIBUTION HAS STARTED UPWARD

CONSTANTS AND FORMULAS

APPENDIX F

Film Build Cpk's Cost Impact Analysis

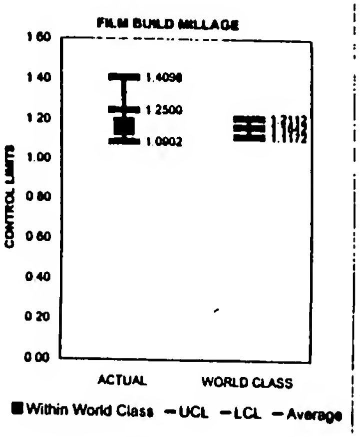
1ST PREMISE

VARIATION SELECTION
1) Choose Variability
2) Select First Target Range
3) Average Adjusted to World Class Standard

Coating: Black Prime
Panel: Hood
Booth: na

Coating Min. Spec.:	0.9
Actual Average:	1.25
Actual Range:	0.68
Actual Cpk:	0.587
Subgroup Size:	14
Target Range:	0.2
World Class Cpk:	1.5
Effect on Coating Usage	**-6.87%**

Approximate Annualized Cost Impact
$ (3,754.55)



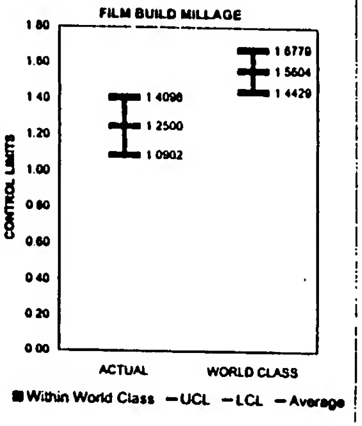
2ND PREMISE

VARIATION SELECTION
1) Choose Variability
2) Select Second Target Range
3) Average Adjusted to World Class Standard

Coating: Black Prime
Panel: Hood
Booth: na

Coating Min. Spec.:	0.9
Actual Average:	1.25
Actual Range:	0.68
Actual Cpk:	0.587
Subgroup Size:	14
Target Range:	0.5
World Class Cpk:	1.5
Effect on Coating Usage	**24.83%**

Approximate Annualized Cost Impact
$ 13,577.12



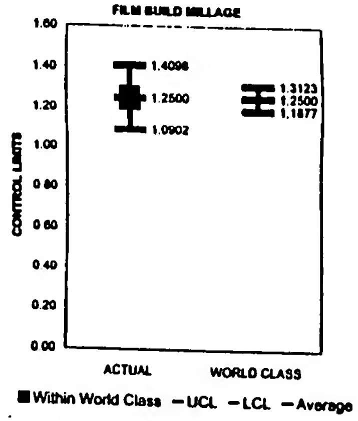
3RD PREMISE

VARIATION REDUCTION
1) Variability Adjusted to World Class Standard
2) Coating Usage Remains Consistent
3) Average Remains Constant

Coating: Black Prime
Panel: Hood
Booth: na

Coating Min. Spec.:	0.9
Actual Average:	1.25
Actual Range:	0.68
Actual Cpk:	0.587
Subgroup Size:	14
New Range:	0.27
World Class Cpk:	1.5
Effect on Coating Usage	**0.00%**

Approximate Annualized Cost Impact
$ nil



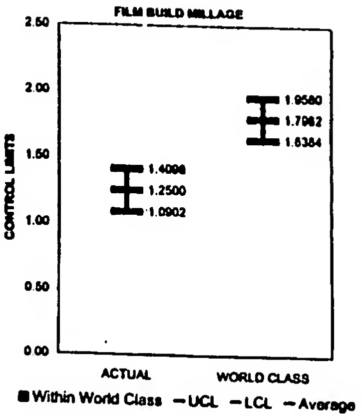
4TH PREMISE

INCREASED MILLAGE
1) Coating Usage Increases
2) Variability Remains Constant
3) Average Adjusted to World Class Standard

Coating: Black Prime
Panel: Hood
Booth: na

Coating Min. Spec.:	0.9
Actual Average:	1.25
Actual Range:	0.68
Actual Cpk:	0.587
Subgroup Size:	14
New Average:	1.7982
World Class Cpk:	1.5
Effect on Coating Usage	**43.85%**

Approximate Annualized Cost Impact
$ 23,976.12



Cost per Unit Factors:

Coating:	Panel:	Usage per Unit (gal.):	Cost per Gallon ($):	Coating Popularity %:	Panel %:	Booth % Flow:	Annualized Production (units):
Black Prime	Hood	0.27	27	25	15	100	200,000

Automotive Facility
Booth 2 Clear Coat Film Build Cost Analysis

Panel	Millage Adjusted, Variability Constant	Range Variability Adjusted: 0.10 Mils	Range Variability Adjusted: 0.20 Mils
Left	$ 214,576	$ 7,333	$ 25,674
Right	$ 263,413	$ 22,571	$ 41,838
Hood	$ 161,393	($ 39,670)	($ 23,712)
Roof	$ 84,819	($ 19,053)	($ 505)
Deck	$ 40,453	($ 20,413)	($ 10,903)
Totals:	$ 764,654	($ 49,232)	$ 32,392

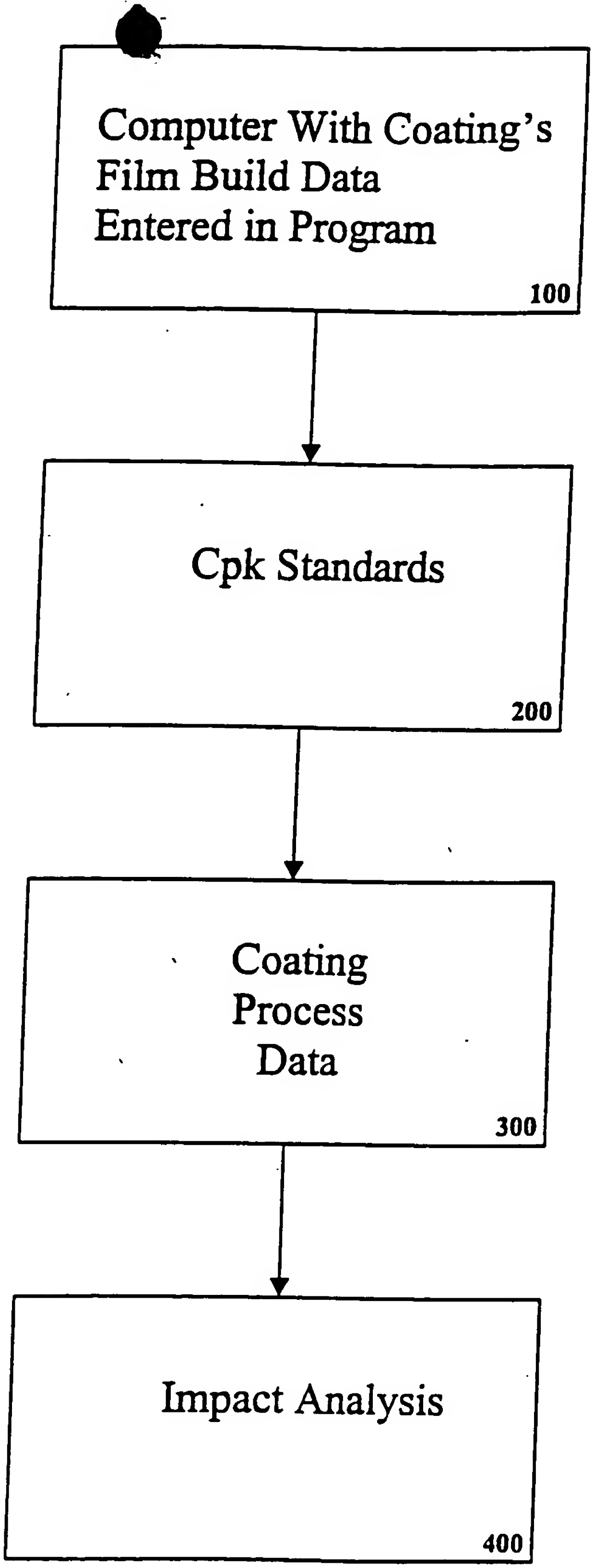

Computer With Coating's Film Build Data Entered in Program
100
Cpk Standards
200
Coating Process Data
300
Impact Analysis
400

FIGURE 1

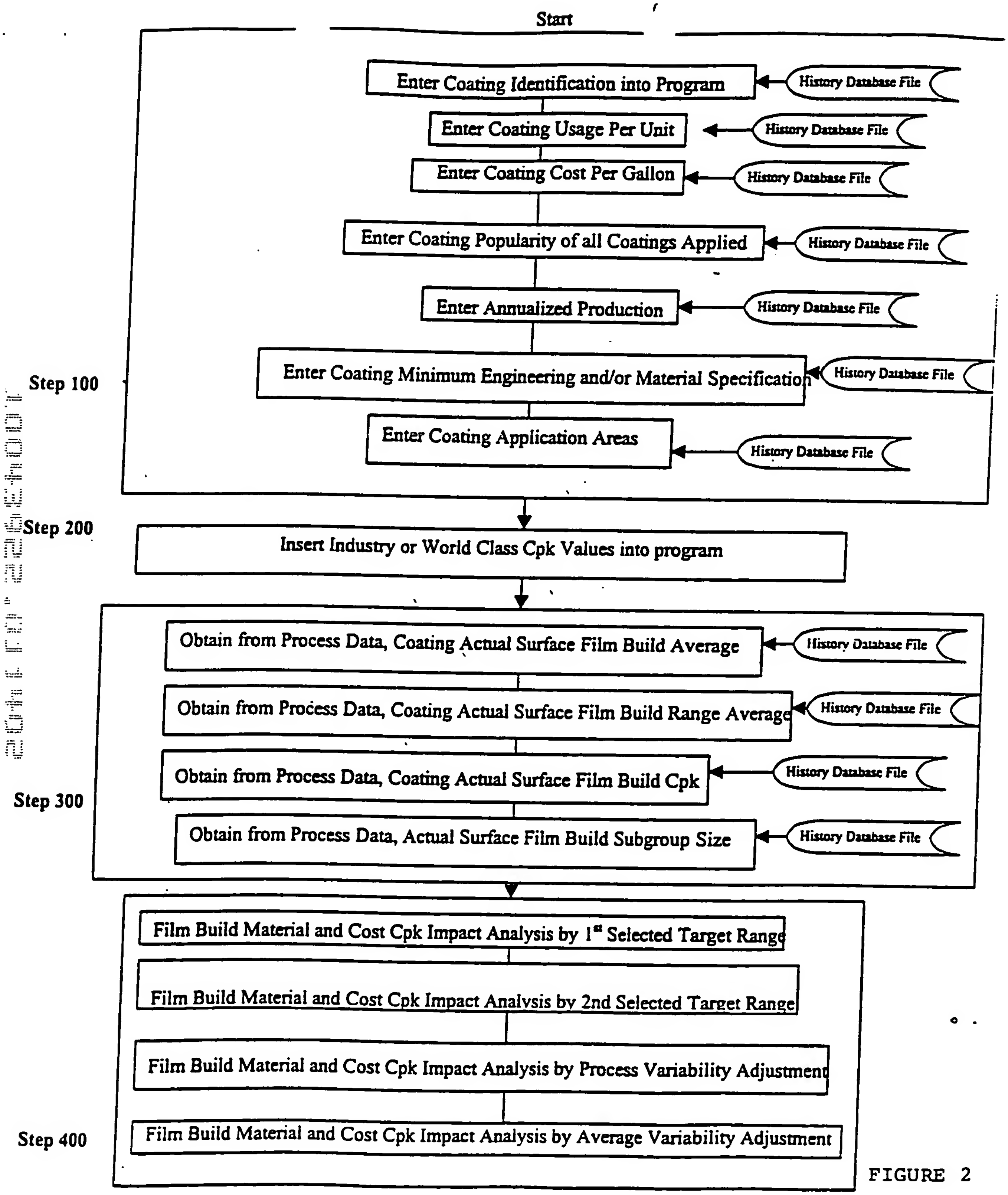

Start
Enter Coating Identification into Program
History Database File
Enter Coating Usage Per Unit
History Database File
Enter Coating Cost Per Gallon
History Database File
Enter Coating Popularity of all Coatings Applied
History Database File
Enter Annualized Production
History Database File
Step 100
Enter Coating Minimum Engineering and/or Material Specification
History Database File
Enter Coating Application Areas
History Database File
Step 200
Insert Industry or World Class Cpk Values into program
Obtain from Process Data, Coating Actual Surface Film Build Average
History Database File
Obtain from Process Data, Coating Actual Surface Film Build Range Average
History Database File
Obtain from Process Data, Coating Actual Surface Film Build Cpk
History Database File
Step 300
Obtain from Process Data, Actual Surface Film Build Subgroup Size
History Database File
Film Build Material and Cost Cpk Impact Analysis by 1st Selected Target Range
Film Build Material and Cost Cpk Impact Analysis by 2nd Selected Target Range
Film Build Material and Cost Cpk Impact Analysis by Process Variability Adjustment
Step 400
Film Build Material and Cost Cpk Impact Analysis by Average Variability Adjustment

FIGURE 2